

**STATUS OF THE DEVELOPMENT OF A MINIMUM
PERFORMANCE STANDARD FOR HALON REPLACEMENT
AGENTS IN AIRCRAFT CARGO COMPARTMENTS**

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International Aircraft Fire and Cabin Safety Research Conference
November 16-20, 1998
Atlantic City, NJ

Abstract

This paper describes the fire scenarios that have been developed to certify replacement fire suppression systems for cargo compartments. All of the cargo compartments on transport aircraft that require fire suppression systems currently use total flood Halon 1301 systems. Eventually Halon 1301 will not be a viable option for cargo compartment fire protection because of the ban on production of new Halon 1301 that became effective in January, 1994. The fire scenarios and acceptance criteria in the Minimum Performance Standard will be used to ensure that the replacement systems or agents maintain the same level of protection currently provided by the existing halon systems. The four fire scenarios include a surface burning class B fire, a deep seated class A fire, a containerized class A fire, and a simulated bursting aerosol can with hydrocarbon propellant.

Purpose

The purpose of this paper is to discuss the development of the Minimum Performance Standards (MPS) for aircraft cargo compartment fire suppression systems. The standards will be used to evaluate the performance of suppression systems or agents intended as replacements for current Halon 1301 systems to ensure the replacements maintain an equivalent level of safety.

Introduction

Current aviation regulations require fire suppression systems for some classifications of cargo compartments. In the past, the aircraft industry has always selected Halon 1301 (CF_3Br , Bromotrifluoromethane) total flood fire suppression systems as the most efficient and effective systems to comply with the regulations. Halon has been identified as one of the substances contributing to stratospheric ozone depletion and its production has been banned in most industrialized countries since 1994. Large quantities of halon still exist in storage facilities throughout the world but there is increasing pressure in some countries to destroy some of the existing stockpiles. At some point, halon will no longer be a viable choice for cargo compartment suppressions systems.

Much research has occurred over the last several years into replacement agents or systems for halon. This research has identified new agents or systems that can suppress fires but all the replacements have some disadvantages compared with Halon. Some of the disadvantages include one or more of the following: additional weight and/or volume, increased toxicity, corrosion concerns, clean up requirements, and increased maintenance or system complexity.

Aviation regulations never specifically required the use of Halon 1301 systems. The regulations only state that the fire suppression system must be effective in controlling any fires likely to occur. Because of the widespread use of halon for many years, the effectiveness on different types of fires has become the accepted level of protection for cargo compartment fire protection. The minimum performance standards described in this paper are meant to ensure that replacement agents or systems for halon maintain this currently acceptable level of safety.

These standards are being developed through the International Halon Replacement Working Group (IHRWG). This group is made up of representatives from regulatory agencies, aircraft manufacturers, airlines, fire suppression and detection suppliers, research institutes, and military organizations throughout the world. The working group meets regularly to discuss all aspects of Halon replacement issues and to present results of fire testing. Minimum performance standards have or will be developed for other aircraft applications using Halon 1301 or Halon 1211. These include engine nacelles and Auxiliary Power Units (APUs), hand held extinguishers, and lavatory trash receptacles. The cargo compartment minimum performance standards presented here are not yet finalized.

Fire Scenarios

The most difficult task in the development of the cargo MPS was to identify the fire scenarios on which the replacement agents or systems must demonstrate their effectiveness. Aircraft cargo compartment fires are relatively rare events. The source of ignition is sometimes never determined and when it is the causes are very diverse. A valid statistical base does not exist for determining what fire scenarios are the most likely to occur because each actual occurrence is usually unique. Rather than duplicate an actual fire scenario that might or might not ever occur again, two generic fire scenarios were initially chosen. These were a deep seated class A fire involving shredded newspaper in cardboard boxes and a class B fire involving surface burning of a flammable liquid. The class A fire scenario was further sub divided into a fire inside a cargo container and a fire in a bulk loaded compartment. This was done because of the different challenge to a fire suppression system when the fire might initially be shielded from the suppression agent in the case of the containerized cargo loading versus the bulk loading of individual pieces of cargo directly into the compartment. Containerized cargo loading is common on wide body aircraft and bulk loading is common on narrow body aircraft. A fourth fire scenario was also added because of the recognized threat of aerosol cans in passenger luggage. These items are probably one of the most common hazardous materials carried in the cargo compartments of passenger carrying aircraft. The propellant used in typical aerosol cans is a mixture of propane, butane and isobutane. The burst strength of a common aerosol can is approximately 210 lbs/in². Raising the temperature of the propellant mix to as little as 200° F will usually exceed the burst strength and the can will fail violently. The released propellant will ignite in the presence of an ignition source and may produce a large fireball and overpressure. The overpressure associated with the ignition of the propellant is sufficient to dislodge the cargo liners which are designed to relieve large pressure differences between the compartment and the rest of the pressurized fuselage. When this occurs there is a path for the fire to spread outside the compartment and the ability of the compartment to contain suppression agent and products of combustion is lost. The presence of aerosol cans in passenger luggage is so prevalent that this fire scenario was considered to be a likely event.

Test Article

The test article selected for conducting all the required tests was a below floor cargo compartment of a wide body aircraft with a volume of 2000 ft³. The ventilation rate from the compartment was set at 50 ft³/min. It was recognized that the outcome of fire suppression tests is very dependent on the size, shape and ventilation rate of the test article among many other things and there are good arguments for conducting the tests in a compartment exactly like the aircraft compartment that the suppression system is designed for. The major problem in conducting all the tests in the MPS required compartment is that the system needed for the MPS compartment may be significantly different than the system designed for the actual compartment if the size, shape and ventilation rates are different. An example of this would be if the actual airplane compartment has a much lower ventilation rate than the MPS requirement and a single initial discharge of agent would provide sufficient concentration for the 30 minute test

duration. The same initial concentration would decay faster in a compartment with a higher ventilation rate and might not be adequate for the 30 minute test in the MPS compartment. If the tested system is a local application system such as a fluid spray system there could be significant differences in nozzle spacing, flow rates, orientation, etc. between the MPS required cargo compartment size and shape and the actual airplane compartment. There are however many advantages to requiring all tests be conducted in a single compartment. Most airplanes use one central supply of suppression agent to protect 2 or 3 different cargo compartments. The compartments are invariably of different sizes. Requiring separate tests in mock ups of each size compartment would be costly and time consuming. In addition, suppression system suppliers might want to conduct their own tests to help certify an agent or system that could be applicable to many different aircraft. Requiring tests in every size and shape compartment that they might want to market their system to would be prohibitive. Current aviation regulations require that a flight test be performed to demonstrate the adequacy of the fire suppression system. This test is not a fire test but a measure of the dispersion of the suppression agent and the duration of protection. This test would still be required in addition to the MPS fire test. It would ensure the adequacy of the replacement system even if the quantities and flow rates for the system used on the MPS fire tests was different than the design for the actual aircraft compartment. For these reasons, one generic test article size and shape was selected for the MPS tests.

Suppression System Activation

All classifications of cargo compartments that require suppression systems also require fire detection systems. Current fire detection systems all rely on the detection of smoke particles through light scattering, light attenuation or ionization types of detectors. There is variability in the alarm points of detectors between manufacturers and also in the product lines of the same manufacturer. The fire detection systems in existing aircraft is completely independent of the fire suppression systems and they are certified in separate tests. In FAA research testing of water spray fire suppression systems it was necessary to employ system feedback capability to optimize the quantity of water needed to control the test fires. The systems were divided into relatively small zones and the water spray in each zone was activated independently depending on the temperature within the zone. It was assumed that if such a system was ever installed on an aircraft the requirement to measure zone temperatures to optimize the system would also be part of the initial detection system. This led to the question of whether detection and suppression systems that are not independent could be used to initially activate the suppression system for the MPS tests. This could lead to different size initial fires and therefore different challenges to the suppression system being tested, depending on detection systems. It was recognized that if a combined detection and suppression system would result in faster or slower detection times then it would make sense to subject the replacement suppression system to that smaller fire or larger fire. However, the potential issues that could arise from a combined detection and suppression test were determined to be too complex to be fully addressed in the MPS. Some of the issues were what would be done if the temperature measuring sensors were changed to a different manufacturer after the MPS test was completed and how the response time might change, how the detection times

would vary in compartments of different size and shape than the MPS requirement, what would be the effect on the control of the fire if one or more temperature sensors malfunctioned and would MPS fire tests be required to demonstrate control of the fire under those conditions. For these and other reasons it was decided to keep the detection system separate from the MPS test even though it was recognized that less water or other fluid might be required if the systems were combined.

The suppression system activation time for the bulk load, containerized load and surface burning fire scenarios was chosen as sixty seconds after any ceiling thermocouple reached 200° F. That temperature was chosen to ensure that the fire was sufficiently developed so that it would not self extinguish. The sixty second delay was chosen somewhat arbitrarily to simulate the flight crew reaction time that would occur in a real incident of a fire detection warning. The delay would be caused by the crew actions of referring to the flight manual for the cargo smoke checklist, selecting which cargo compartment to discharge into, shutting off ventilation fans if needed, and any other required actions.

Toxicity

Toxicity was another issue that generated a great deal of debate in the development of the MPS. Current regulations require that there are means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by passengers or crewmembers. Flight tests are required to show compliance with this regulation. Hazardous gases are caused by a combination of the products of combustion from the cargo fire, by the decomposition of the fire suppression agent when exposed to high temperature, and by the suppression agent itself. The inflight airflow patterns inside a fuselage determine the movement of possibly hazardous gases into occupied areas. These patterns are different for each type of airplane and vary with the flight profile. A test article that could replicate a range of inflight airflow patterns in the cabin above the cargo compartment and the analytical instruments needed to measure a variety of toxic gases would be prohibitive for most companies wishing to conduct these tests. The MPS therefore addresses toxicity by only providing guidance material to be used when selecting an agent for a fire suppression system. Toxicity issues would have to be addressed by the certifying official on a case by case basis depending on the particular suppression agent or system.

Halon 1301 Effectiveness

Baseline testing has been completed using Halon 1301 on the bulk load, containerized load and surface burning fire scenarios. The aerosol can scenario development had not been completed at the time this paper was written. The performance of currently used halon systems on the fire scenarios in this MPS is the acceptance criteria for any replacement systems. Performance can be judged in many different ways but it was decided that temperatures produced by the test fires during suppression was the most practical method of assessing replacement agents. Temperatures measured on the ceiling and upper sidewall of the cargo compartment did not exceed 700° F starting 30 seconds

after the discharge of the halon system for the bulk load and containerized load fire scenarios in the baseline halon testing. The peak temperatures occurred very early in the test and temperatures gradually subsided into the 300° F to 400° F range. Selecting an acceptance criteria whereby no ceiling or sidewall thermocouple would be permitted to exceed 700° F starting 30 seconds after suppression system activation would not accurately represent the effectiveness of the halon system. Further refinement of the acceptance criteria was necessary.

The cargo compartment test article was lined with galvanized steel to protect the structure and allow repeated testing with minimal refurbishment time. The temperatures generated by these fires are not sufficient to melt galvanized steel so in the absence of any suppression system, oxygen starvation will control the fires to a certain degree. A test was conducted without any suppression system used at all. The area under the time-temperature curve for the ceiling thermocouple that recorded the highest temperature was computed. This area is representative of the heat output of the fire. The area under the temperature curve for the test with no suppression system was significantly higher than for the tests using halon. However, if temperatures not exceeding 700° F was the sole acceptance criteria then in theory, ceiling temperatures of 700° F for the full 30 minute test duration would be acceptable. This situation is unlikely but would be permitted. The area under the curve for a 700° F temperature for 30 minutes is much greater than the area under the curve for the test using no suppression system at all. To better represent the effectiveness of current halon systems, a second acceptance criteria was added that limited the heat produced by the test fires by setting an upper limit on the area under the time-temperature curve for the ceiling thermocouple that recorded the maximum temperature after suppression system activation.

Summary

The fire scenarios developed for the cargo compartment minimum performance standard were chosen because they represent in a general way the types of fires and conditions that could occur and pose a threat to flight safety. The scenarios are a fair challenge to any of the types of halon replacement agents or systems that have been identified to date. Some of these systems are very different than the gaseous total flood systems currently in use. The scenario most difficult for current halon systems to control might not be the most difficult for some of the replacement systems.

Full scale fire testing as described in the MPS will invariably produce a range of results because all of the factors that affect the combustion process cannot be practically controlled to the degree necessary to conduct completely repeatable tests. The test article, fuel loads, and parameters required to be measured during the tests were purposefully selected to be the best compromise between the need to keep the test requirements as simple as possible so that the maximum number of companies could conduct testing on their own and to be sufficiently repeatable to give consistent and meaningful results.